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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 595

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. ▼ October 11, 1917

WINTER WHEAT IN THE GREAT PLAINS AREA

RELATION OF CULTURAL METHODS TO PRODUCTION

By

E. C. CHILCOTT, Agriculturist in Charge, JOHN S. COLE, Agriculturist, and J. B. KUSKA, Assistant,
Office of Dry-Land Agriculture

CONTENTS

	Page		Page
Introduction	1	Results at the Several Stations	10
Area Included in These Investigations	2	General Discussion of Results	29
Climatic Conditions	3	Comparison of Winter Wheat with Spring Wheat	32
General Plan of the Investigations	4	Conclusions	34
Comparison of Cultural Methods	7		

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All of the members of the scientific staff of the Office of Dry-Land Agriculture have contributed more or less to this bulletin by having charge of field investigations and by assisting in the preparation of data for records or for publication. The scientific staff as at present constituted consists of the following members named in the order of length of service: E. F. Chilcott, Woodward, Okla.; O. J. Grace, Akron, Colo.; J. S. Cole, Washington, D. C.; J. M. Stephens, Moccasin, Mont.; A. L. Hallsted, Hays, Kans.; O. R. Mathews, Belle Fourche, S. Dak.; J. C. Thysell, Dickinson, N. Dak.; M. Pfaender, Mandan, N. Dak.; W. M. Osborn, Lawton, Okla.; W. D. Griggs, Dalhart, Tex.; J. E. Mundell, Big Spring, Tex.; F. L. Kelso, Ardmore, S. Dak.; W. A. Peterson, Mandan, N. Dak.; J. T. Sarvis, Mandan, N. Dak.; G. W. Morgan, Havre, Mont.; H. G. Smith, Tucumcari, N. Mex.; L. N. Jensen, Amarillo, Tex.; R. S. Towle, Edgeley, N. Dak.; A. J. Ogaard, Hettinger, N. Dak.; C. B. Brown, Garden City, Kans.; L. D. Willey, Sheridan, Wyo.; J. B. Kuska, Colby, Kans.; A. E. Seamans, Huntley, Mont.; L. L. Zook, North Platte, Nebr.; C. H. Ruzicka, Williston, N. Dak.; A. W. Schulz, Mandan, N. Dak.; R. W. Wilson, Mandan, N. Dak.; W. E. Lyness, Archer, Wyo.; F. A. Wagner, Big Spring, Tex.; H. J. Clemmer, Woodward, Okla.; F. E. Cobb, Mandan, N. Dak.; A. Osenbrug, Scottsbluff, Nebr.; J. F. Brandon, Akron, Colo.; and T. P. Baird, Moccasin, Mont.

The following-named men have held positions on the scientific staff of the Office of Dry-Land Agriculture during the past nine years, but have resigned or have been transferred to other offices of the Department of Agriculture: Sylvester Balz, F. L. Kennard, J. E. Payne, L. E. Hazen, C. A. Jensen, H. R. Reed, W. O. Whitcomb, C. H. Plath, F. Knorr, R. W. Edwards, H. C. McKinstry, C. A. Burmeister, J. G. Lill, W. W. Burr, and J. H. Jacobson.

The data here reported from the stations in Kansas, Nebraska, North Dakota, and Montana have been obtained in cooperation with the agricultural experiment stations of the respective States. In South Dakota, Colorado, Texas, Oklahoma, and New Mexico the stations are operated by the United States Department of Agriculture.

Field, office, and laboratory facilities, teams, and implements have been provided by the Office of Western Irrigation Agriculture at Huntley, Mont., Belle Fourche, S. Dak., and Mitchell, Nebr., and by the Office of Cereal Investigations at Amarillo, Tex., and Archer, Wyo. The Biophysical Laboratory has cooperated in obtaining the meteorological data reported.

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CONTENTS.

	Page.		Page.
Introduction	1	Results at the several stations	10
Area included in these investigations	2	General discussion of results	29
Climatic conditions	3	Comparison of winter wheat with spring wheat	32
General plan of the investigations	4	Conclusions	34
Comparison of cultural methods	7		

INTRODUCTION.

This bulletin contains a study of the yields of winter wheat obtained under various methods of seed-bed preparation at 13 field stations in the Great Plains region.

The study as here made shows the effect of the cropping and cultivation of the land in only the one year preceding the growth of the winter wheat. A study of the cost of production by each of the methods under trial and the resulting profit or loss is also given. There is also presented for comparison the average yields and the resulting profits or losses from spring wheat grown by the same methods at the same stations for the same years.

Results are presented from an aggregate of 75 station years, involving an aggregate of 1,137 plat years. By "station year" is meant one year at one station; by "plat year" is meant one plat at one station for one year.

Such a mass of material furnishes an infinite amount of detail for study, but it is the purpose of this bulletin to consider only the broader bearings and more obvious and important phases of the work rather than a study of the details.

This bulletin, dealing with only one crop, does not afford a measure for judging the agricultural possibilities for other crops of any section of the Great Plains area. The Office of Dry-Land Agriculture of the United

[1] For a list of members of the scientific staff of the Office of Dry-Land Agriculture, cooperating stations, etc., see the second page of the cover.

Note.—This bulletin is intended for all who are interested in the agricultural possibilities of the Great Plains area.

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States Department of Agriculture began field work in the investigation of methods of crop production in this area in 1906. The work begun at that time has been constantly added to until 24 stations were in operation in 1916. Data from only 13 of these stations are here presented; those that have been operated less than four years are not included.

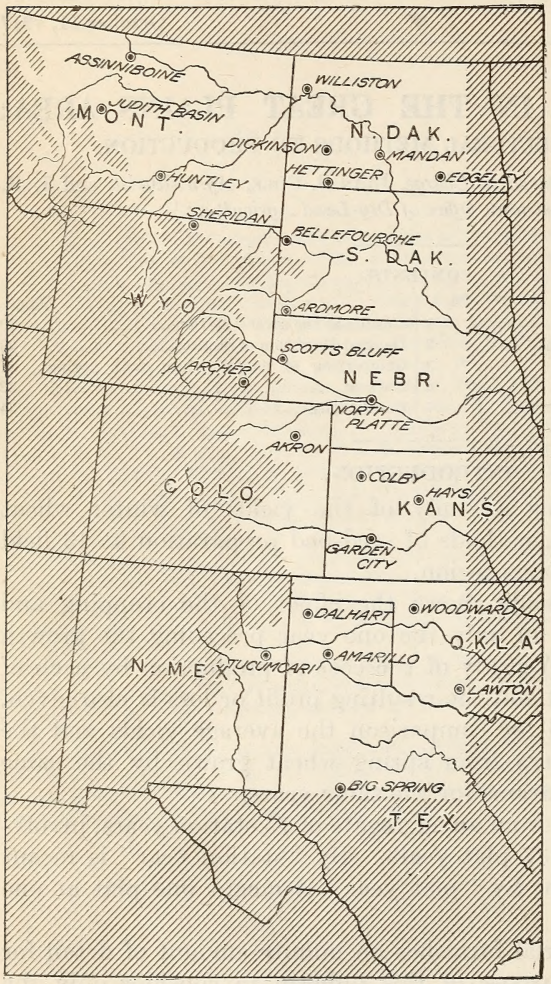

FIG. 1.—Sketch map of the Great Plains area, which includes parts of ten States and consists of about 400,000 square miles of territory. Its western boundary is indicated by the 5,000-foot contour. The location of each field station within the area is shown by a dot within a circle (⊙).

The method of work adopted was that of raising the different crops both in different combinations or systems of rotation and under different methods of cultivation in systems of continuous cropping. In no case have rotations of more than six years in length been used. Those of even this length have been tried only with sod crops. More of the work has been done with 3-year and 4-year rotations.

AREA INCLUDED IN THESE INVESTIGATIONS.

The area covered by these investigations is shown in figure 1 and consists of about 400,000 square miles of territory. It includes the western portions of North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas, and the eastern portions of Montana, Wyoming, Colorado, and New Mexico. As no varieties of winter wheat have yet been found which are able to survive the winter in North Dakota, this crop is not included in the work at the North Dakota stations. The fact that limited rainfall is the determining factor in crop production is responsible for a general uniformity in condi-

tions throughout the area. There is, however, a wide range of soil, climatic conditions, and altitude. The lowest station where winter wheat is grown is Hays, Kans., with an altitude of 2,050 feet, and the highest is Archer, Wyo., with an altitude of 6,012 feet. The length of the growing season for winter wheat is naturally much the same throughout the area, but there is a variation of approximately a month to six weeks in the respective dates of seeding and harvesting. The northern stations seed somewhat earlier than the southern, while the southern stations harvest earlier than the northern.

CLIMATIC CONDITIONS.

The Great Plains area is characterized by a varying amount of annual and seasonal precipitation, with very uncertain distribution. Years of relatively high precipitation with favorable distribution may be followed by years of relatively low precipitation with very unfavorable distribution. It may be said that the uncertainty of the distribution rather than the total amount of rainfall received is the factor that makes crop production hazardous. In connection with this work, complete climatic data have been obtained. It is not practicable, however, to present them in this publication. Table I shows the minimum, maximum, and average annual and seasonal rainfall and the seasonal evaporation at each station for the years for which the yields are here reported. By seasonal is meant the precipitation or evaporation for the period between the average time of growth beginning in the spring and the average time of harvesting. No attempt is made here to show any of the other climatic factors or the amount of water already in the soil at seeding time, any of which might have an important influence on yields. The annual precipitation as here given is not the average as determined from the complete record, but is the average annual precipitation of the years whose results are under study

TABLE I.—*Annual and seasonal precipitation and seasonal evaporation at thirteen stations in the Great Plains area.*[1]

Station.	Altitude[2] (feet).	Precipitation[3] (inches).						Seasonal evaporation[4] (inches).		
		Annual.			Seasonal.					
		Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.
Judith Basin	4,228	14.96	23.78	18.31	6.50	11.06	9.03	18.544	26.273	21.205
Huntley	3,000	11.92	17.54	13.79	5.00	11.83	7.62	18.486	21.799	20.175
Belle Fourche	2,950	6.64	21.02	13.96	1.92	15.38	8.04	18.388	33.906	25.415
Ardmore	3,557	13.23	30.41	17.66	6.93	20.34	11.14	19.555	28.140	24.828
Archer	6,012	11.77	18.32	14.16	4.64	10.16	7.12	20.056	27.320	24.319
Scottsbluff	3,950	9.95	23.58	15.44	6.75	10.78	8.31	23.006	27.620	25.556
North Platte	3,000	11.18	34.85	19.31	5.61	23.52	11.09	24.621	35.255	29.620
Akron	4,600	13.74	25.00	18.22	6.60	14.17	9.67	21.796	33.114	28.449
Hays	2,050	15.59	32.90	21.45	3.87	16.58	10.41	22.402	41.317	31.333
Garden City	2,900	9.70	26.51	18.05	5.01	10.95	7.51	29.802	39.354	35.144
Dalhart	4,000	13.69	22.81	16.67	4.54	14.86	8.21	31.854	41.002	37.813
Amarillo	3,676	10.69	27.80	18.61	5.03	11.49	7.11	29.647	40.704	36.130
Tucumcari	4,194	10.89	22.24	17.12	2.83	11.07	7.03	32.285	42.405	37.139

[1] The years covered are the same as for the data shown in the other tables for each station.

[2] The altitude given is for the field where the work was done and is based in most cases on that of the nearest town.

[3] The seasonal rainfall is the amount from Apr. 1 to July 31 for stations north of and including Akron. For stations south of Akron it is the amount between Mar. 1 and June 30.

[4] The evaporation is figured from April 1 to July 31.

GENERAL PLAN OF THE INVESTIGATIONS.

The same variety of winter wheat is used on all plats at a station during any one year. The intention is to use the best variety that is available for general use. Changes are made only when seed breeding, selection, or varietal testing make available for general use a better variety. No attempt is made to use the same variety at different stations. The only varieties that have been used, however, have been strains of Turkey and Kharkof. The rate, time, and manner of seeding are the same for all plats at a station in any one year. As compared with more humid sections, the seeding is light, the usual rate being 3 pecks per acre. All seeding is done with a drill, the rows being spaced from 6 to 8 inches apart, depending upon the locality. In different places different styles of drills are used.

At each station the plats are one-tenth acre in size. Their dimensions are 2 by 8 rods. Along their larger dimension the plats are separated by bare alleys 4 feet in width. The ends of the plats are separated by roads 20 feet wide.

There are as many field plats devoted to each rotation as there are years required to complete the cycle of the rotation. Each crop in a rotation is thus grown each year.

Each rotation is given a number, and each plat within the rotation is designated by a letter.

In addition to rotations or different combinations of crops and cultural methods, there is at each station a series of plats continuously cropped by different methods to each of the important crops. With each crop in this series two plats, known as C and D, are alternately cropped and summer tilled.

In the present study a table is presented for each station. The first part of such table shows the yields that have been obtained in each year by each of the different methods under which winter wheat has been grown, considering only the variations in the one year preceding the crop. The previous crop whose stubble was treated as specified is also shown. Where more than one plat has been under the same treatment for the previous year, only the average yield of the whole number of plats so grown is given. Column 2 of the table shows the number of plats so averaged. The succeeding columns need no explanation, as they show the yields for each year as indicated and the averages of each method for the whole period of years. In the last column, where the average appears under the heading "Average," the calculation is from the left. The averages of the different methods of treatment are the averages of the whole number of plats that entered into their composition. For a rough comparison of seasons the bottom line of the first half of the table gives the averages of all plats for each

year, the average of the yearly yields appearing in the last column to the right. (See Tables V to XVIII.)

As here presented, the treatment of the land is specified as early fall plowed, late fall plowed, subsoiled, listed, disked, green manured, and summer tilled. Under these headings are subdivisions to show the preceding crop. At the Judith Basin and Huntley stations, on account of the lateness of the harvest, the plats in the "Early fall plowed" and the "Late fall plowed" columns are plowed at the same time, the former deep, 8 inches, and the latter shallow, about 4 inches.

Where winter wheat follows winter wheat, the system has been that of continuous cropping.

Early fall plowing is done as early as practicable after harvest and to a good depth, the standard being set at 8 inches. The ground after being plowed is given sufficient cultivation with the disk and harrow, if necessary, to form a good seed bed. On one plat which is continuously cropped to winter wheat at each station late fall plowing is shallow, only about 4 inches, and is given a minimum of cultivation.

Subsoiling is done on land continuously cropped to winter wheat. The treatment of the plat that appears at some stations under this heading is the same as the treatment of the plat that appears under "Early fall plowed," except that it is subsoiled. At the time of plowing, a subsoiler is run in each alternate furrow to an additional depth of 6 to 8 inches, making a total depth of about 14 inches. This usually is done two years in succession and then omitted for two years.

The plat that appears at some stations under the heading "Listed," following winter wheat, is continuously cropped to winter wheat. After harvest this plat is furrowed out with the lister instead of being plowed. It is worked down level and the seed bed prepared without the use of the plow.

The plats on disked corn ground are all in rotation with other crops. Both 3-year and 4-year rotations comprise this series. The other crops may be oats, barley, green manure, or potatoes. In some rotations summer tillage replaces one of the crops.

Where winter wheat is grown after a green-manure crop, the system is that of a 4-year rotation in which there is a row crop and one of the small grains. In some of the 4-year rotations summer tillage is substituted for the second small-grain crop. Rye and field peas are used as green-manure crops. At Hays, Garden City, Dalhart, and Amarillo cowpeas were used instead of field peas during the first years.

The method of summer tillage practiced is of an intensive type. The land lies fallow for a year. It is kept clear of weeds and as far as practicable a mulch is maintained on it during the summer pre-

ceding the seeding of the wheat. In some cases it is necessary to plow the land more than once during the period, in order either to maintain a surface receptive to water and resistant to blowing or to prevent the growth of weeds. As practiced, this is an expensive system of production. Experiments are under way to determine the most economical method of summer tillage. The indications are that a less intensive method than that practiced in the work here reported will give practically as good returns.

The yields given in these tables begin with the second year of crop production at each station. The first year's crop is produced on land uniform in its treatment.

Where an entire crop has been lost by hail or other agency that could not possibly be overcome by cultivation, the year is not counted in computing averages. Such failures must, of course, enter into the final results of agricultural endeavor. They are, however, of such uncertain occurrence that the series of years here considered is too short to permit an attempt to establish their normal frequency for any locality. This is in effect what would be done by including them in averages. It is believed that less error is introduced by recognizing their occurrence and excluding them from averages. When the loss of a crop is due to conditions that might possibly have been overcome by cultural practices, a zero yield for that year is included in the calculations.

Embodying the basic data given in Tables II, III, and IV, the second part of the table for each station has been compiled. In this are brought together in summary form the yields detailed in the first part of such table. The value of the average yields thus obtained is calculated and given, together with a computation of the cost of production. The last line of the table gives the profit or loss resulting from the production of winter wheat by the method stated. Loss is indicated by the minus sign. In this second part of each table there are two general headings, "Tillage treatment" and "Previous crop." Under the first heading the plats are grouped entirely by treatment without considering the previous crop. Under the second heading treatment is not considered, and the grouping is entirely governed by the crop immediately preceding the winter wheat. This really makes two tables combined in one, with subdivisions common to both. (See Tables V to XVIII.)

Some of the rotations are calculated to conserve or increase the fertility of the soil, while others may perhaps deplete it. In the present stage of the work, the effects of rotations as units are greatly overshadowed by the effects of the cropping and cultivation of a single year. This is due to the fact that the controllable factors are the water supply, the physical condition of the seed bed, and a certain recognized, if not understood, effect of the crop immediately preceding. Uniformity in these factors is largely restored by the

cultivation or cropping of a single season. After a careful study of the data, it seemed advisable two years ago to prepare a series of bulletins covering the results relating to a single crop as determined by the treatment of the land in only the one year immediately preceding the growth of that crop. Such a series of bulletins was published, but owing to the comparatively small amount of data on winter wheat available at that time, this crop was not included. The addition of the results of the two years that have since elapsed now warrants a publication of the same character relating to winter wheat.

COMPARISON OF CULTURAL METHODS.

The methods under study vary a great deal in the labor involved and in the consequent cost of production by each method. Table IV has therefore been compiled in order to show the average cost by each of the methods under study. These data have been prepared from the records of 10 representative stations, and an average of the records of 6.7 years at each station has been used in preparing it. This is equivalent to a record of 67 years at one station. An accurate record has been kept of all the farm operations performed in the various methods under trial. These have been averaged for the 10 stations. The amount of work required for some methods of treatment varies with the season and with the soil, and the expense of some operations varies with the soil. The amount of labor performed under each of the methods was neither more nor less than that which the man in charge believed to be necessary to bring about the results sought.

In computing the cost of the various operations a fixed wage of $2 a day for a man and $1 a day for a horse was adopted. This may be above or below the actual labor cost in any particular locality, but it is believed to be a fair average and one that will afford a profitable market to the farmer for his labor. The time required of men and teams to cover a given acreage in each of the several farm operations obviously varies with soil and other conditions. The average shown in Table II has been determined from the actual experience of a large number of men connected with these investigations, experience that has extended over a wide range of conditions and many years of time.

The factors included in the cost of production are calculated on an acre basis for each of the separate operations performed, beginning with the preparation of the land and ending with the harvesting and shocking of the grain. To these items are added the cost of seed at 75 cents per acre, interest and taxes on the land investment, calculated at 8 per cent on a valuation of $20 per acre, and the deterioration and repairs of the binder at 15 cents per acre. No allowance is made for the deterioration of other farm equipment, as it is believed that the wages allowed for men and teams are sufficient to cover this

item for the remainder of the equipment. The above-mentioned items are fixed charges per acre—that is, they do not vary greatly with the yield per acre except for the item of twine—but this variation is not sufficient to affect materially the relative total cost of production under the several methods.

Table II shows the cost per acre, based upon what is considered an average day's work for each of the farm operations involved at the above-mentioned wage. As before stated, the type of soil and seasonal conditions will determine to a certain extent the labor requirement and the consequent cost per acre.

TABLE II.—*Average cost per acre*[1] *of the farm operations involved in growing winter wheat in the Great Plains area.*

[The wage scale assumed is $2 per day for each man and $1 per day for each horse.]

Operation.	Force employed.		Day's work.	Item cost.	Cost per acre.
	Men.	Horses.			
			Acres.		
Plowing	1	4	3½	.....	$1.71
Disking	1	4	8	.....	.75
Harrowing	1	4	35	.....	.17
Subsoiling	1	3	3½	.....	1.43
Drilling	1	4	15	.....	.40
Cultivating	1	4	16	.....	.38
Listing	1	4	10	.....	.60
Harvesting:					
Cutting and binding	1	4	15	$0.40	.93
Shocking	1	.....	.....	.13	
Twine	.....	.....	.....	.25	
Binder wear and repair	.....	.....	.....	.15	

[1] The cost of thrashing is not included in the cost per acre, but it is estimated at 10 cents per bushel and deducted from the price of 80 cents in the granary, thus giving a value of 70 cents per bushel in the shock.

The average farm price of wheat used in these computations is based on the data given in Table III, furnished by the Bureau of Crop Estimates of the United States Department of Agriculture. The four States of Kansas, Nebraska, North Dakota, and South Dakota were selected, because their extensive wheat production has given them established market prices which are not greatly influenced by local conditions.

TABLE III.—*Average price*[1] *of wheat at the farm granary for ten years in four States of the Great Plains area.*

[The quotations are given in cents per bushel. Those for the year 1914 are for the date of Nov. 1; in other years Dec. 1 is taken as the date.]

Year.	North Dakota.	South Dakota.	Nebraska.	Kansas.	Average.	Year.	North Dakota.	South Dakota.	Nebraska.	Kansas.	Average.
1905	69	67	66	71	68½	1911	89	91	87	91	89½
1906	63	61	57	58	59¾	1912	69	69	69	74	70½
1907	87	89	79	82	84¼	1913	73	71	71	79	73½
1908	92	92	84	88	89	1914	97	90	92	94	94¼
1909	92	90	89	96	91¾						
1910	90	89	80	84	85¾	Average.	82	81	77	82	80½

[1] The figures in this table are the same as those used in Bulletin No. 214, "Spring Wheat in the Great Plains Area," published by the Office of Dry-Land Agriculture in 1915. The table has not been revised to include 1915 and 1916 because the prices during these two years have been largely determined by the abnormal conditions occasioned by the European war.

As given in Table III, the average farm price of wheat on December 1 for the 10 years preceding 1915 has been, in round numbers, 80 cents per bushel. It costs about 10 cents per bushel to take the grain from the shock, thrash it, and put it in the granary on the farm. This cost per bushel does not vary greatly with the yield and is therefore a fixed price per bushel instead of a fixed price per acre, as is the case with the other costs of production. The relative profits of producing winter wheat under the different methods can therefore best be determined by finding the difference between the fixed cost per acre and the value per acre of the grain at the point where the fixed cost per acre ends, which, as before stated, is when the grain is in the shock. Knowing that the average farm value of winter wheat in the granary is 80 cents per bushel and that it costs 10 cents per bushel to take it from the shock, thrash it, and put it in the granary, it is obvious that it would be worth 70 cents per bushel in the shock. This valuation of 70 cents per bushel has therefore been used as a basis for calculating the relative crop values, costs, and profits per acre of the various methods under trial.

TABLE IV.—*Cost per acre of producing winter wheat in the shock in the Great Plains area, showing averages of data for ten stations.*

Method of preparation.	Number of operations.							
	Plowing.	Harrowing.	Disking.	Subsoiling.	Listing.	Drilling.	Leveling.[1]	Cultivating.
Disked corn		0.5	1.3					
Listed					1		1	
Late fall plowed	1	1.1	.2					
Early fall plowed	1	1.7	1.7					
Subsoiled	1	1.7	1.7	0.5				
Summer tilled	1.5	5.8	3.8					1
Green manured:								
With rye[2]	2	4.8	3.6			1		.5
With peas[3]	2	4.8	3.6			1		.5

Method of preparation.	Cost of preparation.	Cost per acre.			Interest and taxes.	Total cost of production.	
		Seed.	Drilling.	Harvesting.		Per acre.	In bushels, at 70 cents per bushel.
Disked corn land	$0.57	$0.75	$0.40	$0.93	$1.60	$4.25	6.1
Listed	1.75	.75	.40	.93	1.60	5.03	7.2
Late fall plowed	1.97	.75	.40	.93	1.60	5.65	8.1
Early fall plowed	2.64	.75	.40	.93	1.60	6.32	9.0
Subsoiled	3.25	.75	40	.93	1.60	7.03	10.0
Summer tilled	5.36	.75	.40	93	3.20	10.64	15.2
Green manured:							
With rye.[2]	7.18	.75	.40	.93	3.20	12.46	17.8
With peas[3]	10.18	.75	.40	.93	3.20	15.46	22.1
Average cost of green manuring						13.96	19.9

[1] The cost of leveling listed ground for seeding is estimated at 75 cents per acre.
[2] The cost of rye for seeding 1 acre is estimated at $1.
[3] The cost of peas for seeding 1 acre is estimated at $4.

In conformity with the foregoing explanation, Table IV gives in detail the cost of producing winter wheat in the shock, expressed in dollars and cents and in bushels per acre at 70 cents per bushel. These prices are used as a working basis and are not offered as being exact. It is fully realized that the price of any or all factors used in obtaining them may vary locally from the fixed price assumed.

RESULTS AT THE SEVERAL STATIONS.

Accompanying the discussion of each station is a very brief description of the soil, with particular reference to its depth and its water-holding capacity. Only such information is given as is necessary to understand fully the interpretation of the results.

JUDITH BASIN FIELD STATION.

The field station at Moccasin, Mont., in the Judith Basin, is located on a heavy clay soil of limestone origin. The soil is apparently very rich in available fertility. It is underlain at a depth of approximately 3 feet by a limestone gravel that is closely cemented with lime materials. The gravel subsoil, which extends to a depth of about 30 feet, is practically free from soil. While it is so closely cemented that it does not unduly drain the soil, it is not of a character that allows the storage of available water or the development of roots within it. Gravel in the surface soil interferes with the taking of samples satisfactory for the study of soil moisture. Enough has been done, however, to make it certain that the supply of water that can be stored in this soil is limited. This shallowness of the soil and consequent limitation of the quantity of water that can be stored in it and recovered by the crop makes the crop dependent in large part upon the rains that fall while it is growing.

The first winter wheat raised at the station was the crop of 1909, which was all on summer-tilled land. The first crop which shows results from different methods of preparation is that of 1910.

In the period under study, there has been one failure of winter wheat, the crop of 1916 being lost by winterkilling. In 1912 the crop was badly damaged by a hailstorm that entirely destroyed the spring-sown grains.

The highest average yield, 25.7 bushels per acre, has been obtained from summer tillage. The yields from summer tillage have been the highest every year except in 1910. The next highest average yield, 24.4 bushels, was secured after green-manure crops. The yields after green manure have been higher than from any other method, except summer tillage, every year except in 1912. Since 1914, when the practice of seeding on disked corn ground was begun, this method has outyielded all others except green manuring and summer tillage. During this period, the yields after summer tillage have averaged 5.5 bushels greater than on disked corn ground.

The yields obtained from deep plowing, deep plowing and subsoiling, and the shallow plowing of winter-wheat stubble have shown only very small differences. Listing has averaged approximately 1 bushel per acre less than plowing. The highest average yield from any of these methods is 6.1 bushels less than after green manure and 7.4 bushels less than from summer tillage. During the three years that seeding on disked corn ground has been practiced the yields from this method have averaged 6.3 bushels higher than any of the other continuous-cropping methods used.

TABLE V.—*Yields and cost of production of winter wheat by different methods at the Judith Basin Field Station, 1910 to 1916, inclusive.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).							
		1910	1911	1912	1913	1914	1915	[a] 1916	Average.
Deep fall plowed: Winter wheat	1	24.0	23.5	12.2	23.2	16.3	28.5	0	18.2
Shallow fall plowed: Winter wheat	1	23.8	22.0	13.2	25.5	16.3	25.0	0	18.0
Listed: Winter wheat	1	21.7	22.3	10.8	24.3	20.1	21.1	0	17.2
Subsoiled: Winter wheat	1	23.2	22.4	12.5	26.2	15.5	28.3	0	18.3
Disked: Corn	4	.....	.....	.....	.....	22.5	38.1	0	20.2
Green manured:									
With rye	3	.....	[b] 30.5	[b] 11.2	[b] 31.3	[c] 23.6	49.5	0	24.4
With peas	2	.....	.....	.....	.....	[d] 23.1	50.5	0	24.5
Total or average	5	.....	[b] 30.5	[b] 11.2	[b] 31.3	[e] 23.5	49.9	0	24.4
Summer tilled	4	[f] 22.0	[f] 31.6	[f] 17.5	[f] 31.8	25.5	51.5	0	25.7
Average of all 17 plats	.....	22.9	25.4	12.9	27.1	21.0	42.1	0	21.6

SUMMARY OF YIELDS AND DIGEST OF COST.

Yields, values, etc. (average per acre).	Tillage treatment.							Previous crop.	
	Deep fall plowed (1 plat).	Shallow fall plowed (1 plat).	Listed (1 plat).	Subsoiled (1 plat).	Disked (4 plats).	Green manured (5 plats).	Summer tilled (4 plats).	Winter wheat (4 plats).	Corn (4 plats).
Yields of grain:									
1910 bushels	24.0	23.8	21.7	23.2	.....	.....	[f] 22.0	23.2	.....
1911 do	23.5	22.0	22.3	22.4	.....	[b] 30.5	[f] 31.6	22.6	.....
1912 do	12.2	13.2	10.8	12.5	.....	[b] 11.2	[f] 17.5	12.2	.....
1913 do	23.2	25.5	24.3	26.2	.....	[b] 31.3	[f] 31.8	24.8	.....
1914 do	16.3	16.3	20.1	15.5	22.5	23.5	25.5	17.1	22.5
1915 do	28.5	25.0	21.1	28.3	38.1	49.7	51.5	25.7	38.1
1916 [a] do	0	0	0	0	0	0	0	0	0
Average	18.2	18.0	17.2	18.3	20.2	24.4	25.7	17.9	20.2
Crop value, cost, etc.:									
Value	$12.74	$12.76	$12.04	$12.81	$14.14	$17.08	$17.99	.....	.....
Cost	6.32	5.65	5.03	7.03	4.25	13.96	10.64	.....	.....
Profit	6.42	6.95	7.01	5.78	9.89	3.12	7.35	.....	.....

[a] The failure of winter wheat in 1916 was due to winterkilling.
[b] One plat, 1911 to 1913, inclusive.
[c] Two plats of rye in 1914.
[d] One plat of peas in 1914.
[e] Three plats in 1914.
[f] One plat, 1910 to 1914, inclusive.

The highest profit, $9.89 per acre, was obtained from disked corn ground. The value of this method as a farm practice will depend upon the profitable growth and utilization of the corn crop. Of the continuous-cropping methods, listing (on account of its inexpensiveness) has produced the next highest profit, which is $2.88 per acre less than the profit on disked corn ground.

Table V shows the profit from summer tillage to be next to that on disked corn ground. In the case of summer tillage and green manuring, however, the fact must be taken into account that a profit is secured only once in two years on the same ground. Green manuring, being even more expensive and less productive than summer tillage, has been the least profitable method. No difference is to be noted between peas and winter rye for green manure.

HUNTLEY FIELD STATION.

The field station at Huntley, Mont., is located in the valley of the Yellowstone River, just below the first bench. The soil is a heavy gumbo to a depth of about 8 feet. Underlying the soil is a considerable depth of freely drained gravel. This soil carries a large supply of available water and allows deep feeding of the crop; consequently, it is possible to store in it a maximum quantity of water that can be recovered by the crop.

The Huntley station presents for study three years' results from some methods and four years' results from others.

As judged by average yields (Table VI), the methods practiced divide sharply into four groups, the production of the best method being more than double that of the poorest. These groups are summer tillage, with an average yield of 39.4 bushels; green manure, 30.6 bushels; disked corn ground, 25.8 bushels; and the various methods of preparing land continuously cropped to winter wheat, with averages ranging from 17.2 to 19 bushels per acre. The differences within this latter group are too small to be decisive, particularly as they are not consistent from year to year. As between peas and winter rye for green manure the advantage at this station is decidedly in favor of peas. In only one of the four years for which comparison is afforded has the yield following rye as green manure exceeded that following peas. The average yield after peas has been 5.2 bushels per acre greater than that after rye.

As judged by relative profits per acre, two methods—summer tillage, with an average profit of $16.94 per acre, and disked corn ground, with an average profit of $13.81 per acre—stand out as being distinctly superior to any of the other methods. The relatively high profit from summer tillage is due to the very high yield from that method, but the superiority of disked corn ground over the other methods, while due largely to high yields, may be attrib-

uted in part to the relatively low cost of the method. The profits of all other methods under trial range from $5.72 on deep fall plowing of winter wheat stubble to $7.92 on listed wheat stubble.

TABLE VI.— *Yields and cost of production of winter wheat by different methods at the Huntley Field Station, 1913 to 1916, inclusive.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).				
		1913	1914	1915	1916	Average.
Deep fall plowed: Winter wheat	1	.....	25.7	13.3	12.7	17.2
Shallow fall plowed: Winter wheat	1	.....	30.8	12.3	13.7	18.9
Listed: Winter wheat	1	.....	26.2	13.1	16.3	18.5
Subsoiled: Winter wheat	1	.....	27.8	13.6	15.5	19.0
Disked: Corn	4	27.4	31.5	26.8	17.3	25.8
Green manured:						
With rye	2	22.8	36.3	37.5	14.9	27.9
With peas	2	36.9	33.5	38.7	23.4	33.1
Total or average	4	29.9	34.9	38.2	19.2	30.6
Summer tilled	3	41.6	40.6	[a] 56.1	[b] 19.4	39.4
Average of all 15 plats	.....	32.2	33.2	[c] 38.0	[d] 18.0	30.4

SUMMARY OF YIELDS AND DIGEST OF COST.

Yields, values, etc. (average per acre).	Tillage treatment.							Previous crop.	
	Deep fall plowed (1 plat).	Shallow fall plowed (1 plat).	Listed (1 plat).	Subsoiled (1 plat).	Disked (4 plats).	Green manured (4 plats).	Summer tilled (3 plats).	Winter wheat (4 plats).	Corn (4 plats).
Yields of grain:									
1913.....bushels	.....	.....	.....	.....	27.4	29.9	41.6	.....	27.4
1914.....do	25.7	30.8	26.2	27.8	31.5	34.9	40.6	27.6	31.5
1915.....do	13.3	12.3	13.1	13.6	26.8	38.2	[a] 56.1	13.1	26.8
1916.....do	12.7	13.7	16.3	15.5	17.3	19.2	[b] 19.4	14.6	17.3
Average	17.2	18.9	18.5	19.0	25.8	30.6	39.4	18.4	25.8
Crop value cost, etc.:									
Value	$12.04	$13.23	$12.95	$13.30	$18.06	$21.42	$27.58	.....	.....
Cost	6.32	5.65	5.03	7.03	4.25	13.96	10.64	.....	.....
Profit	5.72	7.58	7.92	6.27	13.81	7.46	16.94	.....	.....

[a] Eight plats in 1915. [b] Nine plats in 1916. [c] Twenty plats in 1915. [d] Twenty-one plats in 1916.

BELLE FOURCHE FIELD STATION.

The field station near Newell, S. Dak., on the Belle Fourche Reclamation Project, is located on a heavy gumbo clay soil. The soil is derived from the decomposition of Pierre shale. From the soil at the surface there is a rapid change to broken but undecomposed shale. Near the bottom of the second foot is a comparatively impervious layer of soil. The first foot and at least a part of the second foot carry a large supply of available water. It is probable that but little use is made of either water or soil below the first 2 feet. In spite of the heavy soil and the large supply of water that can be obtained by the plant from that portion of it near the surface, the

shallowness of feeding reduces the quantity of available water that can be carried in the soil to about one-half of that available in deeper soils. The result of this is shown in the yields. (Table VII.)

TABLE VII.— *Yields and cost of production of winter wheat by different methods at the Belle Fourche Field Station, 1909 to 1916, inclusive.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).								
		1909	1910	1911	1912	1913	1914	1915	1916	Average.
Early fall plowed: Winter wheat	1	34.4	0	0	0	21.8	13.4	20.4	8.8	12.4
Late fall plowed: Winter wheat	1	19.0	0	0	0	16.2	15.1	34.8	16.1	12.7
Listed: Winter wheat	1	29.3	0	0	0	13.4	15.2	41.2	15.2	14.3
Subsoiled: Winter wheat	1	29.3	0	0	0	18.7	14.7	25.2	8.5	12.1
Summer tilled	1	32.4	9.2	0	0	36.5	32.5	59.3	14.8	23.1
Average of all 5 plats		28.9	1.8			21.3	18.2	36.2	12.7	14.9

SUMMARY OF YIELDS AND DIGEST OF COST.

Yields, values, etc. (average per acre).	Tillage treatment.					Previous crop.
	Early fall plowed (1 plat).	Late fall plowed (1 plat).	Listed (1 plat).	Subsoiled (1 plat).	Summer tilled (1 plat).	Winter wheat (4 plats).
Yields of grain:						
1909 ..... bushels..	34.4	19.0	29.3	29.3	32.4	28.0
1910 ..... do....	0	0	0	0	9.2	0
1911 ..... do....	0	0	0	0	0	0
1912 ..... do....	0	0	0	0	0	0
1913 ..... do....	21.8	16.2	13.4	18.7	36.5	17.5
1914 ..... do....	13.4	15.1	15.2	14.7	32.5	14.6
1915 ..... do....	20.4	34.8	41.2	25.2	59.3	30.4
1916 ..... do....	8.8	16.1	15.2	8.5	14.8	12.2
Average	12.4	12.7	14.3	12.1	23.1	12.8
Crop value, cost, etc.:						
Value	$8.68	$8.89	$10.01	$8.47	$16.17	.....
Cost	6.32	5.65	5.03	7.03	10.64	.....
Profit	2.36	3.24	4.98	1.44	5.53	.....

During the last eight years there have been two total failures of winter wheat (1911 and 1912) at the Belle Fourche station. In 1910 the only wheat produced was 9.2 bushels per acre on summer-tilled land. The average yield from summer tillage is almost double that from any other method, though in 1909 the yield from this method was less than from early fall plowing. Listing has produced the highest average yield of the continuous-cropping methods. While the average result shows a difference of only 0.3 of a bushel between early and late fall plowing, wide differences have been exhibited in the individual years. Generally the early fall plowing is very lumpy and is difficult to work down to form a compact seed bed. In years when there is considerable fall precipitation it is possible to work the

early fall plowing into excellent condition for seeding. When this condition occurs, little difference is shown between early and late fall plowing. In years when the fall precipitation is limited, both the best stand and the best winter survival are found on late fall plowing. This condition is shown particularly in the results of 1915 and 1916. The wide margin of difference in favor of early fall plowing in 1909 is due to the fact that at that time the grass still persisted on the late fall-plowed land. No winter wheat has been sown on disked corn ground at this station.

Summer tillage shows the highest profit, $5.53 per acre. Listing is the most profitable of the continuous-cropping methods. Subsoiling, on account of the expense involved, is the least profitable of the methods studied. Late fall plowing has given appreciably larger net returns than early fall plowing, as the extra labor involved in the latter method on the average does not increase the yield.

ARDMORE FIELD STATION.

Two types of soil are found on the Ardmore farm—Orman clay and Pierre clay. Both of these types hold a high percentage of available water and should show favorable results from the cultural methods that store moisture. In the Orman clay, on which type of soil most of the experiments have been conducted, gravel is found at depths of 2 to 4 feet. Crop yields have not been limited so much by the inability of the soil to hold all of the moisture taken in as by the texture of the soil, which makes penetration of rain on fallow land difficult.

At Ardmore winter wheat failed in 1913 under all methods except summer tillage, which averaged in that year 8 bushels per acre. In 1914 the crop was destroyed by hail. In the other two years under study the yields were good under all methods. Summer tillage has produced the highest average yield, but in 1916 three of the other methods gave higher yields. Early fall plowing, late fall plowing, and listing have averaged approximately the same. The difference in yield between subsoiling and disked corn ground is very small, both averaging considerably higher than early or late fall plowing or listing. (Table VIII.)

The profits from summer tillage and green manuring are decidedly less than from the continuous cropping methods. The highest net return, $11.29 per acre, has been obtained from disked corn ground. Late fall plowing, involving less expense, has been more profitable than early fall plowing. While subsoiling has produced higher yields than listing, the profits from the two methods are approximately equal. On land continuously cropped to winter wheat, higher profits have been secured from subsoiling and listing than from early or late fall plowing.

TABLE VIII.—*Yields and cost of production of winter wheat by different methods at the Ardmore Field Station, 1913 to 1916, inclusive.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).				
		1913	1914	1915	1916	Average.
Early fall plowed: Winter wheat	1	0	(a)	29.2	29.8	19.7
Late fall plowed: Winter wheat	1	0	(a)	30.0	27.0	19.0
Listed: Winter wheat	1	0	(a)	25.0	34.0	19.7
Subsoiled: Winter wheat	1	0	(a)	33.3	34.5	22.6
Disked: Corn	3	0	(a)	36.4	30.1	22.2
Green manured:						
With rye	1	0	(a)	30.2	33.5	21.2
With peas	1	0	(a)	30.8	31.3	20.7
Total or average	2	0	.....	30.5	32.4	21.0
Summer tilled	3	b 8.0	(a)	37.0	31.6	25.5
Average of all 12 plats	.....	c 1.4	.....	33.2	31.3	22.0

SUMMARY OF YIELDS AND DIGEST OF COST.

Yields, values, etc. (average per acre).	Tillage treatment.							Previous crop.	
	Early fall plowed (1 plat).	Late fall plowed (1 plat).	Listed (1 plat).	Subsoiled (1 plat).	Disked (3 plats).	Green manured (2 plats).	Summer tilled (3 plats).	Winter wheat (4 plats).	Corn (3 plats).
Yields of grain:									
1913.....bushels..	0	0	0	0	0	0	b 8.0	0	0
1914.....do....	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
1915.....do....	29.2	30.0	25.0	33.3	36.4	30.5	37.0	29.4	36.4
1916.....do....	29.8	27.0	34.0	34.5	30.1	32.4	31.6	31.3	30.1
Average	19.7	19.0	19.7	22.6	22.2	21.0	25.5	20.2	22.2
Crop value, cost, etc.:									
Value	$13.79	$13.30	$13.79	$15.82	$15.54	$14.70	$17.85	.....	.....
Cost	6.32	5.65	5.03	7.03	4.25	13.96	10.64	.....	.....
Profit	7.47	7.65	8.76	8.79	11.29	.74	7.21	.....	.....

a Destroyed by hail. b Two plats in 1913. c Eleven plats in 1913.

SCOTTSBLUFF FIELD STATION.

The work at Scottsbluff, Nebr., is conducted at a field station located on the North Platte Irrigation Project. The soil is a comparatively light sandy loam. At a depth varying from 5 to 8 feet there is a sharp break from sandy loam to either sand or Brule clay. Above this point the soil offers no unusual resistance to the downward passage of water or to the development of roots. Owing to its light character, however, it is possible to store in it only a moderate supply of available water. In respect to this point it is somewhere intermediate between the Belle Fourche and the North Platte soils.

At the Scottsbluff station summer tillage has produced the highest average yield, though higher yields were produced in 1913 by early fall plowing, disked corn ground, and rye as green manure; in 1914 by disked corn ground and rye as green manure, and in 1916 by rye

and peas as green manure and by disked corn ground. The average yield of 15.4 bushels per acre from disked corn ground is higher than that following any other harvested crop, but is 5.2 bushels less than on summer tillage and 0.7 bushel less than on rye as green manure. The yields after rye as a green-manure crop have been consistently higher than the yields after peas. Ground plowed early in the fall yields nearly twice as much on the average as ground plowed late, but only about three-fifths as much as disked corn ground. The results from listing and subsoiling are not sufficient for comparison with the results obtained from other methods. (Table IX.)

TABLE IX.— *Yields and cost of production of winter wheat by different methods at the Scottsbluff Field Station, 1912 to 1916, inclusive.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).					
		1912	1913	1914	1915	1916	Average.
Early fall plowed: Winter wheat	1	6.3	7.7	17.8	8.7	5.2	9.1
Late fall plowed: Winter wheat	1	0	0	12.8	11.7	2.5	5.4
Listed: Winter wheat	1	.....	.....	.....	.....	3.8	3.8
Subsoiled: Winter wheat	1	.....	.....	22.3	.....	5.0	13.7
Disked: Corn	3	15.6	10.5	18.2	25.7	6.9	15.4
Green manured:							
With rye	1	14.0	9.0	26.7	23.8	7.0	16.1
With peas	1	12.3	6.3	23.3	.....	6.3	12.1
Total or average	2	13.2	7.7	25.0	[a] 23.8	6.7	15.3
Summer tilled	2	20.9	6.8	32.0	37.0	6.2	20.6
Average of all 11 plats	.....	13.5	7.5	22.1	22.2	5.7	14.2

SUMMARY OF YIELDS AND DIGEST OF COST.

Yields, values, etc. (average per acre).	Tillage treatment.							Previous crop.	
	Early fall plowed (1 plat).	Late fall plowed (1 plat).	Listed (1 plat).	Subsoiled (1 plat).	Disked (3 plats).	Green manured (2 plats).	Summer tilled (2 plats).	Winter wheat (4 plats).	Corn (3 plats).
Yields of grain:									
1912.....bushels..	6.3	0	.....	.....	15.6	13.2	20.9	[b] 3.2	15.6
1913.....do....	7.7	0	.....	.....	10.5	7.7	6.8	[b] 3.9	10.5
1914.....do....	17.8	12.8	.....	22.3	18.2	25.0	32.0	[c] 17.6	18.2
1915.....do....	8.7	11.7	.....	.....	25.7	[a] 23.8	37.0	4.1	25.7
1916.....do....	5.2	2.5	3.8	5.0	6.9	6.7	6.2	8.0	6.9
Average	9.1	5.4	3.8	13.7	15.4	15.3	20.6	7.4	15.4
Crop value, cost, etc.:									
Value	$6.37	$3.78	$2.66	$9.59	$10.78	$10.71	$14.42	.....	.....
Cost	6.32	5.65	5.03	7.03	4.25	13.96	10.64	.....	.....
Profit or loss	.05	−1.87	−2.37	2.56	6.53	−3.25	3.78	.....	.....

[a] One plat in 1915. [b] Two plats in 1912 and 1913. [c] Three plats in 1914.

Disked corn ground has averaged the largest profit—$6.53 per acre. The next highest profit has been secured from summer tillage. Excepting subsoiling, since only two years' results are available for

this method, the only other method showing a profit is early fall plowing, with a nominal one of $0.05 per acre. Green manuring and late fall plowing show losses of $3.25 and $1.87 per acre, respectively. The loss shown for listing is for one year, 1916, when none of the methods except disked corn ground produced a profit.

NORTH PLATTE FIELD STATION.

The work here presented is conducted on the table-land of the North Platte Field Station. The soil is of the type generally known as loess. With the exception of the humus accumulated near the surface, it is practically uniform to great depths. The storage and use of water is unlimited by the depth of the soil or any peculiarities in it. The development of roots is limited only by the physiological character of the crops grown and the available moisture. It is a soil on which a maximum of results from tillage methods would be expected.

The highest average yield of winter wheat at the North Platte station has been 22.6 bushels per acre, obtained after rye as a green-manure crop, a yield of 0.5 bushel higher than that on disked corn ground, which shows the next highest average. The yields after peas have averaged 2.3 bushels less than the yields after rye. The yields on disked ground after potatoes, winter wheat, and oats have averaged 3.7, 7.5, and 9 bushels less, respectively, than on disked corn ground. The yields from summer tillage have averaged higher than from any of the continuous cropping methods except disked corn ground. Early fall plowing has given higher yields than late fall plowing, and late fall plowing of winter-wheat stubble has given higher yield than disking winter-wheat stubble. Disked oat ground has given the lowest average yield. The most profitable method has been disked corn ground, with disked potato ground next. Disking as compared with summer tillage, green manuring, or plowing following the same crop has been the more profitable method except where the crop followed oats. Plowing oat stubble has given a sufficiently higher yield than disking the same to make it the more profitable method. On land continuously cropped to winter wheat the average profit from early fall plowing has been the same as from late fall plowing. The profit from summer tillage has been much greater than from green manuring, but less than from any method producing a crop each year. (Table X.)

Winter wheat was grown in field tests at the station during the years 1907 to 1911, inclusive, on land summer tilled the year preceding the wheat crop and on land continuously cropped to winter wheat and early fall plowed. The figures have been published in Nebraska Bulletins Nos. 118 and 135 and in United States Department of Agriculture Bulletin No. 268, entitled "Crop Production in the Great Plains Area." These figures, averaged with the results obtained on

the dry-land agriculture rotations from summer tillage and early fall plowing of winter-wheat stubble for the years 1912 to 1916, inclusive, show an average yield for the 10 years of 30.6 bushels per acre from summer tillage and 15.3 bushels on early fall plowing.

TABLE X.—*Yields and cost of production of winter wheat by different methods at the North Platte Field Station, 1912 to 1916, inclusive.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).					
		1912	1913	1914	1915	1916	Average.
Early fall plowed:							
Winter wheat	1	7.7	3.8	4.7	39.8	28.3	16.9
Winter wheat (manured)	1	9.3	2.2	4.5	31.2	31.3	15.7
Oats	1	10.5	3.8	7.2	42.5	23.0	17.4
Total or average	3	9.2	3.3	5.5	37.8	27.5	16.7
Late fall plowed: Winter wheat	1	7.2	3.2	3.3	39.7	23.5	15.4
Disked:							
Winter wheat	2	1. [illegible]	4.3	3.0	38.0	26.3	14.6
Corn	9	10.0	16.9	8.0	37.3	38.4	22.1
Oats	2	0	7.1	3.3	42.6	12.4	13.1
Potatoes	1	0	14.5	7.5	36.3	33.6	18.4
Total or average	14	6.6	13.5	6.6	38.0	32.6	19.5
Green manured:							
With rye	1	28.2	24.0	8.3	18.3	34.3	22.6
With peas	1	23.8	15.5	11.7	25.3	25.3	20.3
Total or average	2	26.0	19.8	10.0	21.8	29.8	21.5
Summer tilled	5	12.7	23.7	10.1	31.7	30.0	21.6
Average of all 25 plats		9.7	14.4	7.3	35.5	30.9	19.6

SUMMARY OF YIELDS AND DIGEST OF COST.

Yield, values, etc. (average per acre).	Tillage treatment.					Previous crop.				
	Early fall plowed (3 plats).	Late fall plowed (1 plat).	Disked (14 plats).	Green manured (2 plats).	Summer tilled (5 plats).	All small grain (8 plats).	Winter wheat (5 plats).	Oats (3 plats).	Corn (9 plats).	Potatoes (1 plat).
Yields of grain:										
1912.....bushels..	9.2	7.2	6.6	26.0	12.7	4.7	5.4	3.5	10.0	0
1913.....do....	3.3	3.2	13.5	19.8	23.7	4.5	3.5	6.0	16.9	14 5
1914.....do....	5.5	3.3	6.6	10.0	10.1	4.0	3.7	4.6	8.0	7 5
1915.....do....	37.8	39.7	38.0	21.8	31.7	39.3	37.3	42.5	37.3	36.3
1916.....do....	27.5	23.5	32.6	29.8	30.0	22.9	27.1	15.9	38.4	33.6
Average.....	16.7	15.4	19.5	21.5	21.6	15.1	15.4	14.5	22.1	18.4
Crop value, cost, etc.:										
Value.....	$11.69	$10.78	$13.65	$15.05	$15.12	.....	.....	.....	.....	.....
Cost.....	6.32	5.65	4.25	13.96	10.64	.....	.....	.....	.....	.....
Profit.....	5.37	5.13	9.40	1.09	4.48	.....	.....	.....	.....	.....

ARCHER FIELD STATION.

The work at the Archer station is on a very high upland. The soil is a uniform, medium-dark sandy loam, with some fine gravel distributed very evenly through it. At a depth of 3 to 6 feet the soil is underlain with a bed of gravel. Commonly a hardpan of

particles of fine sand cemented together is found overlying this bed of gravel. Water does not leach readily through this compact layer.

The results from the Archer station are so meager that no definite conclusions can be drawn. In 1914 there was a total failure due to winterkilling under all methods, while in 1916 the stands on the disked corn ground and green-manure plats were destroyed by drifting soil from an adjacent field. Summer tillage has produced higher average yields than the continuous cropping methods for which three years' results are available. The average yields from early fall plowing and late fall plowing are approximately equal and are slightly higher than the yields from listing and subsoiling. (Table XI.)

TABLE XI.—*Yields and cost of production of winter wheat by different methods at the Archer Field Station, 1914 to 1916, inclusive.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).			
		1914	1915	1916	Average.
Early fall plowed: Winter wheat	1	0	24.7	7.4	10.7
Late fall plowed: Winter wheat	1	0	25.9	4.2	10.0
Listed: Winter wheat	1	0	21.2	5.4	8.9
Subsoiled: Winter wheat	1	0	24.2	2.4	8.9
Disked: Corn	3	0	27.1	(a)	13.6
Green manured:					
With rye	1	0	25.3	(a)	12.7
With peas	1	0	29.7	(a)	14.9
Total or average	2	.....	27.5	.....	13.8
Summer tilled	3	(b)	26.4	c 11.4	12.6
Average of all 12 plats	.....	.....	26.0	d 6.2	10.7

SUMMARY OF YIELDS AND DIGEST OF COST.

Yields, values, etc. (average per acre).	Tillage treatment.							Previous crop.	
	Early fall plowed (1 plat).	Late fall plowed (1 plat).	Listed (1 plat).	Subsoiled (1 plat).	Disked (3 plats).	Green manured (2 plats).	Summer tilled (3 plats).	Winter wheat (4 plats).	Corn (3 plats).
Yields of grain:									
1914.....bushels..	0	0	0	0	0	0	0	0	0
1915.....do....	24.7	25.9	21.2	24.2	27.1	27.5	26.4	24.0	27.1
1916.....do....	7.4	4.2	5.4	2.4	(a)	(a)	c 11.4	4.9	(a)
Average	10.7	10.0	8.9	8.9	13.6	13.8	12.6	9.6	13.6
Crop value, cost, etc.:									
Value	$7.49	$7.00	$6.23	$6.23	$9.52	$9.66	$8.82	.....	.....
Cost	6.32	5.65	5.03	7.03	4.25	13.96	10.64	.....	.....
Profit or loss	1.17	1.35	1.20	−0.80	5.27	−4.30	−1.82	.....	.....

a Stands destroyed by drifting soil in 1916.
b Two plats in 1914.
c One plat in 1916; stands on the others destroyed by drifting soil.
d Five plats in 1916.

Late fall plowing has been slightly more profitable than either early fall plowing or listing. Green manuring, summer tillage, and

subsoiling have not proved profitable, green manuring showing the greatest loss. As an average for the two years for which results are available from disked corn ground, this method has given much higher net returns than any other method.

AKRON FIELD STATION.

The soil of the field station at Akron, Colo., is of a clay-loam type locally known as "tight land." It is characterized in the native vegetation by a growth of short grass. As it carries in each unit section a considerable supply of water and as it offers no physical obstruction to the development of roots, it is possible to store in it a large quantity of water available to a crop. It is a soil on which maximum results would be expected from methods of tillage calculated to store water. (Table XII.)

TABLE XII.—*Yields and cost of production of winter wheat by different methods at the Akron Field Station, 1910 to 1916, inclusive.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).							
		1910	1911	1912	1913	1914	1915	1916	Average.
Early fall plowed: Winter wheat	1	10.3	6.8	26.7	2.0	24.8	20.8	4.2	13.7
Late fall plowed: Winter wheat	1	11.4	1.7	25.8	3.3	24.5	22.0	4.2	13.3
Listed: Winter wheat	1	8.8	6.0	30.0	7.2	21.3	18.2	7.7	14.2
Subsoiled: Winter wheat	1	6.9	3.3	21.2	3.2	24.5	21.0	3.8	12.0
Disked: Corn	3	17.7	3.1	36.3	11.4	27.7	26.2	15.3	19.7
Green manured:									
With rye	4	15.7	3.8	36.8	8.4	26.4	25.7	19.2	19.4
With peas	4	12.7	2.4	33.2	4.2	23.1	13.8	9.7	14.2
Total or average	8	14.2	3.1	35.0	6.3	24.7	19.7	14.5	16.8
Summer tilled	2	18.0	10.5	40.9	12.7	27.0	27.4	24.9	23.1
Average of all 17 plats	.....	14.1	4.3	33.8	7.4	25.3	22.0	13.6	17.2

SUMMARY OF YIELDS AND DIGEST OF COST.

Yields, values, etc. (average per acre).	Tillage treatment.							Previous crop.	
	Early fall plowed (1 plat).	Late fall plowed (1 plat).	Listed (1 plat).	Subsoiled (1 plat).	Disked (3 plats).	Green manured 8 plats).	Summer tilled 2 plats).	Winter wheat (4 plats).	Corn (3 plats).
Yields of grain:									
1910.....bushels..	10.3	11.4	8.8	6.9	17.7	14.2	18.0	9.4	17.7
1911.....do....	6.8	1.7	6.0	3.3	3.1	3.1	10.5	4.5	3.1
1912.....do....	26.7	25.8	30.0	21.2	36.3	35.0	40.9	25.9	36.3
1913.....do....	2.0	3.3	7.2	3.2	11.4	6.3	12.7	3.9	11.4
1914.....do....	24.8	24.5	21.3	24.5	27.7	24.7	27.0	23.8	27.7
1915.....do....	20.8	22.0	18.2	21.0	26.2	19.7	27.4	20.5	26.2
1916.....do....	4.2	4.2	7.7	3.8	15.3	14.5	24.9	5.0	15.3
Average	13.7	13.3	14.2	12.0	19.7	16.8	23.1	13.3	19.7
Crop value, cost, etc.:									
Value	$9.59	$9.31	$9.94	$8.40	$13.79	$11.76	$16.17	.....	.....
Cost	6.32	5.65	5.03	7.03	4.25	13.96	10.64	.....	.....
Profit or loss	3.27	3.66	4.91	1.37	9.54	−2.20	5.53	.....	.....

At the Akron station the highest average yield, 23.1 bushels per acre, has been obtained from summer tillage. The yields from summer tillage have been higher than from any other method each year except in 1914, when the yield on disked corn ground was 0.7 bushel higher. Disked corn ground, with an average of 19.7 bushels, has given the next highest yield. The average after rye as a green-manure crop is 0.3 bushel less than that on disked corn ground, while the average after peas is 5.5 bushels less. The yield after peas every year has been lower than after rye. The yield after peas is no greater than from some of the continuous-cropping methods. There is very little difference in the average yields from early fall plowing, late fall plowing, and listing. Subsoiling has given the lowest average yield.

Disked corn ground has given the highest net returns, $9.54 per acre, almost double the profit from listing, the next most profitable of the continuous-cropping methods. The profit from disked corn ground exceeds that from summer tillage by $4.01. Late fall plowing, while averaging slightly less in yield, has given somewhat higher net returns than early fall plowing, because it is a cheaper method. Subsoiling has been the least profitable of the continuous-cropping methods. The only loss sustained is $2.20 per acre from green manuring. This loss is due entirely to the peas, which show a loss of $5.65, whereas rye has averaged a profit of $1.12 per acre.

HAYS FIELD STATION.

The soil on which the experimental work has been conducted at the station at Hays, Kans., is a heavy silt loam. It can carry a large quantity of water available to a crop. Penetration to the lower depths, however, is slow. The very compact zone in the third foot offers marked resistance both to the downward passage of water and to the development of roots. While the evidence is not as complete as might be desired, it appears that the proportion of water that can be stored in this soil is somewhat above the average.

Summer tillage has produced the highest average yield, 22.7 bushels, of winter wheat at the Hays station, though in 1907, 1914, and 1915 the yields from some of the other methods have exceeded those from summer tillage. The next highest average yields, 19.6 and 19.2 bushels, were obtained from subsoiling and listing, respectively. The average yield of 17.6 bushels from early fall plowing is 6.6 bushels greater than that from late fall plowing, the yields from the former method being larger than from the latter method every year except in 1908. Disked corn ground has averaged 2.2 bushels less than early fall plowing and 4.4 bushels more than late fall plowing. The yields from green manuring average 5.7 bushels less than for summer tillage and are lower than from any of the other methods except late fall plowing and disked corn ground. The yields after

rye and after peas average practically the same, though in 1908 the yield after peas was very much lower and in 1910 very much higher than the yield after rye. Previous to 1910 cowpeas were used instead of common field peas. (Table XIII.)

TABLE XIII.— *Yields and cost of production of winter wheat by different methods at the Hays Field Station, 1907 to 1916, inclusive.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).										
		1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	Average.
Early fall plowed: Winter wheat	1	18.2	23.2	[a] H	27.8	0.3	13.8	2.3	24.8	[b] 18.1	[b] 29.7	17.6
Late fall plowed: Winter wheat	1	11.7	25.6	H	20.3	0	2.3	.8	20.6	9.3	8.7	11.0
Listed: Winter wheat	1	12.4	28.1	H	36.7	.6	26.6	8.4	23.1	13.9	23.1	19.2
Subsoiled: Winter wheat	1	13.6	30.5	H	39.8	.3	20.1	4.1	25.3	14.9	27.6	19.6
Disked: Corn	4	8.2	11.1	H	28.2	.3	13.6	7.2	18.0	20.1	31.7	15.4
Green manured:												
With rye	2	10.9	22.5	H	26.8	1.8	6.6	8.4	21.7	20.8	31.3	16.8
With peas [c]	2	14.3	[d] 9.4	H	39.7	2.0	7.5	5.7	23.0	20.9	31.5	17.1
Total or average	4	12.6	[e] 18.1	.....	33.2	1.9	7.0	7.1	21.1	20.8	31.4	17.0
Summer tilled	2	[d] 12.3	30.7	H	42.6	3.9	28.5	13.4	20.8	[f] 16.4	[f] 36.0	22.7
Average of all 14 plats	.....	11.6	20.6	.....	32.5	1.3	14.4	7.1	20.8	[g] 17.0	[g] 33.7	17.7

SUMMARY OF YIELDS AND DIGEST OF COST.

Yields, values, etc. (average per acre).	Tillage treatment.							Previous crop.	
	Early fall plowed (1 plat).	Late fall plowed (1 plat).	Listed (1 plat).	Subsoiled (1 plat).	Disked (4 plats).	Green manured (4 plats).	Summer tilled (2 plats).	Winter wheat (4 plats).	Corn (4 plats).
Yields of grain:									
1907 bushels	18.2	11.7	12.4	13.6	8.2	12.6	[d] 12.3	14.0	8.2
1908 do	23.2	25.6	28.1	30.5	11.1	[e] 18.1	30.7	26.9	11.1
1909 do	[a] H	H	H	H	H	H	H	H	H
1910 do	27.8	20.3	36.7	39.8	28.2	33.2	42.6	31.2	28.2
1911 do	.3	0	.6	.3	.3	1.9	3.9	.3	.3
1912 do	13.8	2.3	26.6	20.1	13.6	7.0	28.5	15.7	13.6
1913 do	2.3	.8	8.4	4.1	7.2	7.1	13.4	3.9	7.2
1914 do	24.8	20.6	23.1	25.3	18.0	21.1	20.8	23.5	18.0
1915 do	[b] 18.1	9.3	13.9	14.9	20.1	20.8	[f] 16.4	[h] 15.4	20.1
1916 do	[b] 29.7	8.7	23.1	27.6	31.7	31.4	[f] 36.0	[h] 24.8	31.7
Average	17.6	11.0	19.2	19.6	15.4	17.0	22.7	18.4	15.4
Crop value, cost, etc.:									
Value	$12.32	$7.70	$13.44	$13.72	$10.78	$11.90	$15.89	.....	.....
Cost	6.32	5.65	5.03	7.03	4.25	13.96	10.64	.....	.....
Profit or loss	6.00	2.05	8.41	6.69	6.53	−2.06	5.25	.....	.....

[a] H=destroyed by hail.
[b] Three plats in 1915 and 1916.
[c] Cowpeas were grown from 1906 to 1909; field peas grown since 1909.
[d] One plat.
[e] Three plats in 1908.
[f] Thirty-one plats.
[g] Forty-five plats in 1915 and 1916.
[h] Six plats in 1915 and 1916.

The highest profit has been obtained from listing, which yields a greater profit than subsoiling, because it is a less expensive method. The profit on disked corn ground is slightly lower than from subsoiling

and somewhat larger than from early fall plowing. The practicability of the method of using disked corn ground depends on the value of the corn crop. Late fall plowing, on account of the poor yields obtained from this method, shows the lowest profit, while summer tillage, on account of the cost of the method, has given next to the lowest profit. The yields from green manuring have not been sufficient to pay the cost of production by this method.

GARDEN CITY FIELD STATION.

The work at Garden City, Kans., is on a high upland. The soil is a light silt loam. With the exception of the accumulated humus near the surface, it is practically uniform to a depth of at least 15 feet. The development of roots is limited only by the depth to which water is available and by the physiological character of the crop. The light character of the soil, however, makes it possible to store in each unit of it only a comparatively small quantity of water. This is not entirely overcome by the depth of the soil. The results in storing water have been determined largely by the limited quantity available for storage. In no year under any method practiced has the soil been filled with water to as great a depth as it is possible for the crop to develop roots and use available water. (Table XIV.)

TABLE XIV.—*Yield and cost of production of winter wheat by different methods at the Garden City Field Station, 1909 to 1916, inclusive.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).								
		1909	1910	1911	1912	[a] 1913	1914	1915	1916	Average.
Early fall plowed: Winter wheat	1	0	0	0	0	.....	6.3	10.0	0	2.3
Late fall plowed: Winter wheat	1	0	0	0	0	.....	7.3	10.0	0	2.5
Listed: Winter wheat	3	0	0	0	0	.....	8.9	12.6	2.1	3.4
Subsoiled: Winter wheat	1	0	0	0	0	.....	16.7	9.9	0	3.8
Disked:										
Corn	[b] 1	0	0	0	0	.....	8.7	16.8	0	3.6
Potatoes	1	.....	.....	.....	.....	.....	7.3	12.8	1.2	7.1
Total or average	2	0	0	0	0	.....	8.0	14.8	.6	3.3
Green manured:										
With rye	[c] 2	0	0	0	0	.....	16.1	9.0	10.0	5.0
With peas	[d] 1	0	0	0	0	.....	14.5	16.8	7.2	5.5
Total or average	[e] 3	0	0	0	0	.....	15.5	11.6	9.1	5.2
Summer tilled	[f] 11	0	0	0	0	.....	12.5	21.3	7.7	5.9
Average of all 22 [g] plats	.....	0	0	0	0	.....	11.4	16.7	5.4	4.8

[a] Birds destroyed the young wheat plants in the fall, and the plats were reseeded to spring wheat.
[b] Two plats, 1909 to 1913, inclusive.
[c] Five plats, 1909 to 1913, inclusive.
[d] Four plats, 1909 to 1913, inclusive.
[e] Nine plats, 1909 to 1913, inclusive.
[f] Two plats, 1909 to 1912, inclusive.
[g] Sixteen plats, 1909 to 1912, inclusive; 29 in 1913.

TABLE XIV.— *Yield and cost of production of winter wheat by different methods at the Garden City Field Station, 1909 to 1916, inclusive*—Continued.

SUMMARY OF YIELDS AND DIGEST OF COST.

Yields, values, etc. (average per acre).	Tillage treatment.							Previous crop.		
	Early fall plowed (1 plat).	Late fall plowed (1 plat).	Listed (3 plats).	Subsoiled (1 plat).	Disked (2 plats).	Green manured (3 plats).[a]	Summer tilled (11 plats).[b]	Winter wheat (6 plats).	Corn (1 plat).[c]	Potatoes (1 plat).
Yields of grain:										
1909....bushels..	0	0	0	0	0	0	0	0	0	.....
1910.....do....	0	0	0	0	0	0	0	0	0	.....
1911.....do....	0	0	0	0	0	0	0	0	0	.....
1912.....do....	0	0	0	0	0	0	0	0	0	.....
1913[d].....do....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1914.....do....	6.3	7.3	8.9	16.7	8.0	15.5	12.5	12.8	8.7	7.3
1915.....do....	10.0	10.0	12.6	9.9	14.8	11.6	21.3	11.3	16.8	12.8
1916.....do....	0	0	2.1	0	.6	9.1	7.4	1.1	0	1.2
Average.....	2.3	2.5	3.4	3.8	3.3	5.2	5.9	3.6	3.6	7.1
Crop value, cost, etc.:										
Value.....	$1.61	$1.75	$2.38	$2.66	$2.31	$3.64	$4.13	.....	.....	.....
Cost.....	6.32	5.65	5.03	7.03	4.25	13.96	10.64	.....	.....	.....
Profit or loss...	−4.71	−3.90	−2.65	−4.37	−1.94	−10.32	−6.51	.....	.....	.....

[a] Nine plats, 1909 to 1913, inclusive.
[b] Two plats, 1909 to 1912, inclusive.
[c] Two plats, 1909 to 1913, inclusive.
[d] Birds destroyed the young wheat plants in the fall, and the plats were reseeded to spring wheat.

Winter wheat was a total failure at the Garden City station every year from 1909 to 1913, inclusive. During these years no method of tillage overcame the unfavorable conditions. As no cultivated land borders on the station, pests, such as rabbits, grasshoppers, and birds, often reduce the yields as much as and sometimes more than unfavorable climatic conditions. Green manuring has never produced profitable yields. Early fall plowing, late fall plowing, and summer tillage produced profitable yields in 1915, while subsoiling yielded a profit in 1914. Disked corn and potato ground and listing were profitable in 1914 and 1915. No method has averaged a profit for the seven years. The average losses per acre range from $1.94 on disked corn and potato ground to $10.32 from green manuring.

DALHART FIELD STATION.

The soil at Dalhart, Tex., is a sandy loam. In some respects it behaves like sand. In other respects it exhibits the characteristics of a heavy clay soil. Its water-holding capacity is comparatively limited. The crops appear, however, to be able to utilize its water to the depth of a normal root development.

At the Dalhart station the crop of winter wheat was totally destroyed by hail in 1910 and 1912, and these years are not used in the averages. In 1909, 1911, 1913, and 1916 no yields were produced from any of the methods. In 1914 all the methods, except summer tillage, produced profitable yields, but that is the only year when

there were any profitable yields. When yields have been secured there have been no marked differences between the various methods. Drought and soil blowing in early spring have been the chief causes of failures and low yields. (Table XV.)

TABLE XV.—*Yield and cost of production of winter wheat by different methods at the Dalhart Field Station, 1909 to 1916, inclusive.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).								
		1909	1910	1911	1912	1913	1914	1915	1916	Average.
Early fall plowed: Winter wheat	1	0	[a]H	0	[a]H	0	10.0	8.3	0	3.1
Late fall plowed: Winter wheat	1	0	H	0	H	0	12.0	5.3	0	2.9
Listed: Winter wheat	1	0	H	0	H	0	10.0	.....	.....	2.5
Disked: Corn	3	0	H	0	H	0	.....	.....	.....	0
Green manured:										
With rye	4	0	H	0	H	0	.....	.....	.....	0
With peas [b]	4	0	H	0	H	0	.....	.....	.....	0
Total or average	8	.....	.....	.....	.....	.....	.....	.....	.....	0
Summer tilled	2	0	H	0	H	0	[c]13.1	[c]8.0	[c]0	3.5
Average of all 16 plats	.....	.....	.....	.....	.....	.....	[d]11.3	[e]7.2	[e]0	3.1

SUMMARY OF YIELDS AND DIGEST OF COST.

Yields, values, etc. (average per acre).	Tillage treatment.						Previous crop.	
	Early fall plowed (1 plat).	Late fall plowed (1 plat).	Listed (1 plat).	Disked (3 plats).	Green manured (8 plats).	Summer tilled (2 plats).	Winter wheat (3 plats).	Corn (3 plats).
Yields of grain:								
1909 bushels	0	0	0	0	0	0	0	0
1910 do	[a]H	H	H	H	H	H	H	H
1911 do	0	0	0	0	0	0	0	0
1912 do	[a]H	H	H	H	H	H	H	H
1913 do	0	0	0	0	0	0	0	0
1914 do	10.0	12.0	10.0	.....	.....	13.1	10.7	.....
1915 do	8.3	5.3	.....	.....	.....	8.0	[f]6.8	.....
1916 do	0	0	.....	.....	.....	0	[f]0	.....
Average	3.1	2.9	2.5	.....	.....	3.5	2.9	0
Crop value, cost, etc.:								
Value	$2.17	$2.03	$1.75	0	0	$2.45	.....	.....
Cost	6.32	5.65	5.03	4.25	13.96	10.64	.....	.....
Profit or loss	−4.15	−3.62	−3.28	−4.25	−13.96	−8.19	.....	.....

[a] H=Destroyed by hail.
[b] Cowpeas grown from 1908 to 1910; field peas grown since 1910.
[c] One plat in 1914, 1915, and 1916.
[d] Four plats in 1914.
[e] Three plats in 1915 and 1916.
[f] Two plats in 1915 and 1916.

AMARILLO FIELD STATION.

The soil at Amarillo, Tex., is a heavy clay silt. It is of the type locally known as "tight land" or "short-grass land." While the evidence is not as complete as could be desired, it appears that the storage of water and the development of the feeding roots of the crop are interfered with by a comparatively impervious layer of soil in the third foot.

The results of eight years are available from Amarillo. The year 1910 was lost by reason of an enforced change in the location of the station. In four of the eight years the yields were fair and in four they were very poor. (Table XVI.)

TABLE XVI.— *Yield and cost of production of winter wheat by different methods at the Amarillo Field Station, 1908 to 1916, inclusive.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).									
		1908	1909	1910[1]	1911	1912	1913	1914	1915	1916	Average.
Early fall plowed: Winter wheat	1	14.3	0	.....	3.5	7.2	1.3	23.0	24.4	3.6	9.7
Late fall plowed: Winter wheat	1	12.7	0	.....	3.1	5.5	0	21.8	18.3	5.8	8.4
Listed: Winter wheat	1	15.3	0	.....	2.2	5.7	1.2	14.2	22.2	6.8	8.5
Subsoiled: Winter wheat	1	16.5	0	.....	1.2	3.3	1.3	19.3	19.7	4.5	8.2
Disked: Corn	2	11.7	0	.....	1.2	10.4	2.0	16.3	11.5	3.6	7.1
Green manured:											
With rye	3	15.0	0	.....	2.1	10.8	2.4	16.4	14.9	4.8	8.3
With peas[2]	3	12.7	0	.....	2.2	10 9	2.7	16.9	11.8	3.9	7.6
Total or average	6	13.8	.....	.....	2.1	10.9	2.5	16.7	13.4	4.3	8.0
Summer tilled	2	16.9	2.9	.....	4.8	12.8	4.3	22.4	15.7	5.3	10.6
Average of all 14 plats	.....	14.2	.4	.....	2.5	9.5	2.3	18.3	15.7	4.6	8.4

SUMMARY OF YIELDS AND DIGEST OF COST.

Yields, values, etc. (average per acre).	Tillage treatment.							Previous crop.	
	Early fall plowed (1 plat).	Late fall plowed (1 plat).	Listed (1 plat).	Subsoiled (1 plat).	Disked (2 plats).	Green manured (6 plats).	Summer tilled (2 plats).	Winter wheat (4 plats).	Corn (2 plats).
Yields of grain:									
1908.....bushels..	14.3	12.7	15.3	16.5	11.7	13.8	16.9	14.7	11.7
1909.....do....	0	0	0	0	0	0	2.9	0	0
1910[1].....do....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1911.....do....	3.5	3.1	2.2	1.2	1.2	2.1	4.8	2.5	1.2
1912.....do....	7.2	5.5	5.7	3.3	10.4	10.9	12.8	5.4	10.4
1913.....do....	1.3	0	1.2	1.3	2.0	2.5	4.3	1.0	2.0
1914.....do....	23.0	21.8	14.2	19.3	16.3	16.7	22.4	19.6	16.3
1915.....do....	24.4	18.3	22.2	19.7	11.5	13.4	15.7	21.2	11.5
1916.....do....	3.6	5.8	6.8	4.5	3.6	4.3	5.3	5.2	3.6
Average.....	9.7	8.4	8.5	8.2	7.1	8.0	10.6	8.7	7.1
Crop value, cost, etc.:									
Value.....	$6.79	$5.88	$5.95	$5.74	$4.97	$5.60	$7.42	.....	.....
Cost.....	6.32	5.65	5.03	7.03	4.25	13.96	10.64	.....	.....
Profit or loss.....	.47	.23	.92	−1.29	.72	−8.36	−3.22	.....	.....

[1] The yields for 1910 are not used, as the station was moved that year.
[2] Cowpeas were grown from 1907 to 1911; field peas since 1911.

In 1909 winter wheat was a total failure at the Amarillo station from all methods except summer tillage, which produced 2.9 bushels per acre.

No method has shown any marked superiority over others in producing yields. The highest average yield, 10.6 bushels per acre by

summer tillage, is 3.5 bushels greater than the lowest average yield, 7.1 bushels, on disked corn ground.

In 1908, 1914, and 1915 all methods except that of green manuring produced profitable yields, and in 1912 there was a profit on disked corn ground. With these exceptions none of the methods have been profitable. As an average for the eight years green manuring, summer tillage, and subsoiling have shown losses of $8.36, $3.22, and $1.29, respectively, while listing, disked corn ground, early fall plowing, and late fall plowing have shown profits of 92, 72, 47, and 23 cents, respectively.

TUCUMCARI FIELD STATION.

The soil at the field station at Tucumcari, N. Mex., is a fine sand. Below the third foot the soil type changes to a loam and then to a clay. The soil drifts quite readily.

During the three years that winter wheat has been grown at this station the crop was a total failure once. In 1915 and 1916 the yields were so small that under no method did the yield of grain pay the cost of production. Drought at critical periods and soil blowing are the chief unfavorable factors. (Table XVII.)

TABLE XVII.— *Yields and cost of production of winter wheat by different methods at the Tucumcari Field Station, 1914 to 1916, inclusive.*

Treatment and previous crop.	Number of plats averaged.	Yield per acre (bushels).			
		1914	1915	1916	Average.
Early fall plowed: Winter wheat	1	0	6.4	1.8	2.7
Late fall plowed: Winter wheat	1	0	7.0	0	2.3
Summer tilled	1	0	5.3	4.0	3.1
Average of all 3 plats			6.2	1.9	2.7

SUMMARY OF YIELDS AND DIGEST OF COST.

Yield, values, etc. (average per acre).	Tillage treatment.			Previous crop.
	Early fall plowed (1 plat).	Late fall plowed (1 plat).	Summer tilled (1 plat).	Winter wheat (2 plats).
Yield of grain:				
1914 ..... bushels	0	0	0	0
1915 ..... do	6.4	7.0	5.3	6.7
1916 ..... do	1.8	0	4.0	.9
Average	2.7	2.3	3.1	2.5
Crop value, cost, etc.:				
Value	$1.89	$1.61	$2.17	
Cost	6.32	5.65	10.64	
Profit or loss	−4.43	−4.04	−8.47	

GENERAL DISCUSSION OF RESULTS.

In the preceding pages data have been presented and briefly discussed separately for each station without reference to results at other stations. In the following pages the data are considered from a more general standpoint. Table XVIII will assist in this study.

TABLE XVIII.—*Comparison of the average yields and profit or loss on the production of winter wheat by different methods at thirteen stations in the Great Plains area.*

Statement of data.	Number of years averaged.	Method of tillage.						
		Early fall plowed.[a]	Late fall plowed.[a]	Listed.	Subsoiled.	Disked.	Green manured.	Summer tilled.
Yields per acre (bushels):								
Judith Basin	7	18.2	18.0	17.2	18.3	[b]20.2	[c]24.4	25.7
Huntley	4	[b]17.2	[b]18.9	[b]18.5	[b]19.0	25.8	30.6	39.4
Belle Fourche	8	12.4	12.7	14.3	12.1	.....	.....	23.1
Ardmore	3	19.7	19.0	19.7	22.6	22.2	21.0	25.5
Archer	3	10.7	10.0	8.9	8.9	[d]13.6	[d]13.8	12.6
Scottsbluff	5	9.1	5.4	[e]3.8	[d]13.7	15.4	15.3	20.6
North Platte	5	16.7	15.4	.....	.....	19.5	21.5	21.6
Akron	7	13.7	13.3	14.2	12.0	19.7	16.8	23.1
Hays	9	17.6	11.0	19.2	19.6	15.4	17.0	22.7
Garden City	7	2.3	2.5	3.4	3.8	3.3	5.2	5.9
Dalhart	6	3.1	2.9	[f]2.5	.....	[b]0	[b]0	3.5
Amarillo	8	9.7	8.4	8.5	8.2	7.1	8.0	10.6
Tucumcari	3	2.7	2.3	.....	.....	.....	.....	3.1
Average	.....	11.8	10.8	11.8	13.8	14.7	15.8	18.3
Average for the 9 stations at which all methods are used	.....	13.1	11.8	12.6	14.0	15.9	16.9	20.7
Profit or loss (−) per acre:								
Judith Basin	7	$6.42	$6.95	$7.01	$5.78	[b]$9.89	[c]$3.12	$7.35
Huntley	4	[b]5.72	[b]7.58	[b]7.92	[b]6.27	13.81	7.46	16.94
Belle Fourche	8	2.36	3.24	4.98	1.44	.....	.....	5.53
Ardmore	3	7.47	7.65	8.76	8.79	11.29	.74	7.21
Archer	3	1.17	1.35	1.20	− .80	[d]5.27	[d]− 4.30	−1.82
Scottsbluff	5	.05	−1.87	[e]−2.37	[d]2.56	6.53	− 3.25	3.78
North Platte	5	5.37	5.13	.....	.....	9.40	1.09	4.48
Akron	7	3.27	3.66	4.91	1.37	9.54	− 2.20	5.53
Hays	9	6.00	2.05	8.41	6.69	6.53	− 2.06	5.25
Garden City	7	−4.71	−3.90	−2.65	−4.37	−1.94	−10.32	−6.51
Dalhart	6	−4.15	−3.62	[f]−3.28	.....	[b]−4.25	[b]−13.96	−8.19
Amarillo	8	.47	.23	.92	−1.29	.72	− 8.36	−3.22
Tucumcari	3	−4.43	−4.04	.....	.....	.....	.....	−8.47

[a] At Huntley and Judith Basin there is no difference in time of plowing. The plats at these stations designated as plowed "early" were plowed deep; those designated as "late" were plowed shallow.
[b] Three years. [c] Six years. [d] Two years. [e] One year. [f] Four years.

In this table the average yields at the several stations are grouped under different methods of preparation. The figures here given are taken from the tables showing details for each station.

Data in regard to yields and cost of production are also assembled in such a way as to show the profit or loss in dollars and cents per acre for the average crop by each method for which it has been computed at each station.

Table XVIII shows that at five of the stations (Judith Basin, Huntley, Belle Fourche, Ardmore, and North Platte) winter wheat has been grown at a profit by all the methods under trial. At two (Akron and Hays) all methods except green manuring have been

profitable. At three (Garden City, Dalhart, and Tucumcari) none of the methods have produced profits. At two (Archer and Amarillo) early and late fall plowing, listing, and disked corn ground have been profitable, the other methods having produced losses. At Scottsbluff early plowing, subsoiling, disked corn ground and summer tillage have returned profits, while late fall plowing, listing, and green manuring have been unprofitable.

As an average for all the stations, early (deep) fall plowing has produced 1 bushel more per acre than late (shallow) fall plowing. The stations that have shown marked differences in the yields of these two methods are Huntley, Scottsbluff, North Platte, Hays, and Amarillo. At Huntley the difference has been in favor of shallow plowing on the average and in each year except 1915. At Scottsbluff, North Platte, Hays, and Amarillo the difference has been in favor of early fall plowing on the average and in each year except at Scottsbluff and North Platte in 1915, at Hays in 1907 and 1908, and at Amarillo in 1916. At Scottsbluff, North Platte, Hays, and Amarillo the profits from early fall plowing are greater, but at the other stations late plowing has been more profitable or has resulted in smaller losses, mainly because it is a less expensive method.

Listing, instead of plowing, wheat stubble after harvest and leveling the ridges preparatory to seeding has averaged 0.9 bushel per acre more than early plowing and 2.2 bushels more than late plowing at the 11 stations where this method has been tried. At five of these stations (Huntley, Belle Fourche, Akron, Hays, and Garden City) it has given higher yields than early fall plowing, and at six (Belle Fourche, Ardmore, Akron, Hays, Garden City, and Amarillo) it has given higher yields than late plowing. Being a cheaper method than plowing, it has been more profitable than early plowing at all of the stations and more profitable than late plowing at all except Archer. At Scottsbluff, Garden City, and Dalhart winter wheat is grown at a loss by this method. At Hays and Amarillo the profits from this method are larger than from any other method under trial.

Subsoiling, as compared with fall plowing similar wheat stubble without subsoiling, has given higher yields at Huntley, Ardmore, Hays, and Garden City. At these stations the average increase due to subsoiling has been more than enough to pay for the extra cost. At Judith Basin and Belle Fourche the yields from the two methods have averaged practically the same, while at Archer, Akron, and Amarillo the differences in favor of plowing without subsoiling are 1.8, 1.7, and 1.5 bushels, respectively. At Scottsbluff, where only two years' results are available for subsoiling, the average yield and average profit are in favor of subsoiling.

Disked corn ground has given consistently high yields. At 6 of the 11 stations where this method has been practiced it has averaged

higher yields than any of the other continuous-cropping methods. Because of the uniformly high yields secured and because of the low cost of preparation, disked corn ground has shown the largest profit at all of the stations except at Huntley, where summer tillage shows $3.13 more profit, at Hays, where listing and subsoiling have netted $1.98 and 18 cents more, respectively, and at Amarillo, where there is a difference of 20 cents in favor of listing. At Garden City, where none of the methods have been profitable, the smallest loss is from disked corn ground, but at Dalhart the loss on disked corn ground has been greater than from any of the other methods except green manuring and summer tillage. The realization of these profits on disked corn ground depends, of course, upon the successful growth of corn as a general farm crop in competition with other crops.

Summer tillage has given the highest average yield of any method under trial at all of the stations except North Platte and Archer, where both green manuring with rye and disked corn ground have averaged higher. As an average for the nine stations at which all of the various methods are practiced, the yield from summer tillage has been 4.8 bushels more than the yield from disked corn ground, the highest yielding of the continuous-cropping methods, and 3.8 bushels more than from green manuring. However, at only one station, Huntley, has summer tillage shown the greatest profit of any of the methods. Summer tillage requires the use of the land two years to produce one crop, and an extra amount of cultivation is necessary to keep the ground free from weeds during the fallow period; consequently, it has the highest acre cost of any method under trial except green manuring. Except at Huntley the increase in yield from this method has been more than offset by the increased cost of production over the cost of the best continuous-cropping methods. It does, however, show a profit at all but five of the stations, and only at Archer and Amarillo has it failed to net a profit when any of the other methods have returned a profit.

Green manuring is the most expensive method under trial. It resembles a fallow in that it requires the use of the land for two years for the production of one harvested crop, with the added expense of seed and seeding. There is a saving in cultivation during the spring while the crop is growing, but this is offset by the necessity of plowing to turn the crop under and is not sufficient to make up for the cost of seed and seeding. Increases in yields have not been commensurate with the cost of producing them. At none of the stations except Archer and North Platte have the yields following any green-manure crop exceeded those from summer tillage. The net returns from green manuring have not been as great as from any of the other methods at any of the stations. A profit has been realized from green manuring at the Judith Basin, Huntley, Ardmore,

and North Platte stations. At the other stations the yields from this method have not been sufficient to pay the cost of producing them, and the losses have been greater than the losses from any other method.

It is hardly fair to charge the whole expense of green manuring to the one crop that immediately follows it, as is done. This method should have a cumulative effect in building up the soil or remedying its deficiency in organic matter. The available evidence is that on normal soils on the Great Plains, at least in the first years of the work, little effect is shown on other than the first crop. This effect is that of a fallow to the extent that the green manure approaches a fallow in the storage of water during the period after the crop is plowed under.

COMPARISON OF WINTER WHEAT WITH SPRING WHEAT.

Table XIX shows the average yields and profit or loss for winter wheat and spring wheat by the different methods under which both of these crops are grown at the 13 stations. This table also gives the average yield and average profit or loss for all of the methods used with each of these crops at each of the stations. The yields from the various methods are comparable for the two crops at each station. The figures used in computing the profit or loss for spring wheat are the same as those used in Table IV in United States Department of Agriculture Bulletin No. 214, entitled "Spring Wheat in the Great Plains Area." Because winter wheat is seeded in the fall, the cost of preparing the ground by the various methods is less than for spring wheat.

At the North Platte, Akron, and Hays stations winter wheat has been distinctly more productive than spring wheat under all methods tried. The greatest differences between the yields of winter wheat and spring wheat have been secured at Hays, where the differences in favor of winter wheat range from 8.6 bushels per acre on disked corn ground to 15.7 bushels on summer tillage. At Tucumcari the yields of spring wheat have been greater than those of winter wheat from the methods under which both crops are grown. The average yield from all the methods used with both crops is decidedly in favor of winter wheat at Huntley and somewhat in favor of winter wheat at Belle Fourche, Scottsbluff, and Amarillo. At the other stations the average yield of spring wheat is slightly greater than the average yield of winter wheat.

The average yield from summer tillage has been decidedly in favor of winter wheat at Judith Basin, Huntley, Belle Fourche, Scottsbluff, North Platte, Akron, and Hays. At Garden City, Dalhart, and Amarillo the average has been slightly in favor of spring wheat, while

at Tucumcari it has been decidedly in favor of spring wheat. At Ardmore and Archer the average yields from summer tillage have been practically equal for the two crops.

TABLE XIX.—*Comparison of the average yields of spring wheat and winter wheat by different methods at thirteen stations in the Great Plains area.*

Statement of data.	Judith Basin (7 years).	Huntley (4 years).	Belle Fourche (8 years).	Ardmore (3 years).	Archer (3 years).	Scottsbluff (5 years).	North Platte (5 years).	Akron (7 years).	Hays (9 years).	Garden City (7 years).	Dalhart (6 years).	Amarillo (8 years).	Tucumcari (3 years).
Yield per acre (bushels).													
Early fall plowed:													
Winter wheat	18.2	17.2	12.4	19.7	10.7	9.1	16.7	13.7	17.6	2.3	3.1	9.7	2.7
Spring wheat	19.7	17.8	13.1	22.3	11.2	8.5	11.6	9.1	5.4	3.8	3.8	8.4	6.8
Listed:													
Winter wheat	17.2	18.5	14.3	19.7	8.9	3.8	.....	14.2	19.2	3.4	2.5	8.5	.....
Spring wheat	20.1	17.6	15.0	16.8	10.0	5.3	.....	10.1	6.5	5.3	5.4	7.0	.....
Subsoiled:													
Winter wheat	18.3	19.0	12.1	22.6	8.9	13.7	.....	12.0	19.6	3.8	.....	8.2	.....
Spring wheat	20.6	17.0	14.0	18.7	10.6	8.3	.....	8.4	5.8	4.7	.....	7.5	.....
Disked:													
Winter wheat	20.2	25.8	.....	22.2	13.6	15.4	22.1	19.7	15.4	3.3	0	7.1	.....
Spring wheat	26.2	24.6	.....	24.2	15.9	14.2	12.1	12.2	6.8	5.7	2.1	7.0	.....
Green manured:													
Winter wheat	24.4	30.6	.....	21.0	13.8	15.3	.....	16.8	.....	.....	0	8.0	.....
Spring wheat	21.0	26.4	.....	24.3	16.2	15.6	.....	11.9	.....	.....	.3	8.5	.....
Summer tilled:													
Winter wheat	25.7	39.4	23.1	25.5	12.6	20.6	21.6	23.1	22.7	5.9	3.5	10.6	3.1
Spring wheat	21.6	26.6	18.2	25.5	12.5	16.6	15.6	16.0	7.0	7.3	6.2	11.5	8.6
Average:													
Winter wheat	20.7	25.1	15.5	21.8	11.4	13.0	20.1	16.6	18.9	3.7	1.8	8.7	2.9
Spring wheat	21.5	21.7	15.1	22.0	12.7	11.4	13.1	11.3	6.3	5.4	3.6	8.3	7.7
Profit or loss (−) per acre.													
Early fall plowed:													
Winter wheat	$6.42	$5.72	$2.36	$7.47	$1.17	$0.05	$5.37	$3.27	$6.00	−$4.71	−$4.15	$0.47	−$4.43
Spring wheat	7.23	5.90	2.61	9.05	1.28	− .61	1.56	− .19	−2.78	− 3.90	− 3.90	− .68	− 1.80
Listed:													
Winter wheat	7.01	7.92	4.98	8.76	1.20	−2.37	.....	4.91	8.41	− 2.65	− 3.28	.92	.....
Spring wheat	8.52	6.77	4.95	6.21	1.45	−1.84	.....	−1.52	−1.00	− 1.84	− 1.77	− .65	.....
Subsoiled:													
Winter wheat	5.78	6.27	1.44	8.79	− .80	2.56	.....	1.37	6.69	− 4.37	.....	−1.29	.....
Spring wheat	7.25	4.73	2.63	5.92	.25	−1.36	.....	−1.29	−3.11	− 3.88	.....	−1.92	.....
Disked:													
Winter wheat	9.89	13.81	.....	11.29	5.27	6.53	11.22	9.54	6.53	− 1.94	− 4.25	.72	.....
Spring wheat	13.59	12.47	.....	12.19	6.38	5.19	3.72	3.79	.01	− .76	− 3.28	.15	.....
Green manured:													
Winter wheat	3.12	7.46	.....	.74	−4.30	−3.25	.....	−2.20	.....	.....	−13.96	−8.36	.....
Spring wheat	.09	3.87	.....	2.40	−3.27	−3.69	.....	−6.28	.....	.....	−14.40	−8.66	.....
Summer tilled:													
Winter wheat	7.35	16.94	5.53	7.21	−1.82	3.78	4.48	5.53	5.25	− 6.51	− 8.19	−3.22	− 8.47
Spring wheat	3.62	7.12	1.24	6.35	−2.75	.12	− .58	− .30	−6.60	− 6.39	− 7.16	−3.45	− 5.48
Average:													
Winter wheat	6.60	9.69	3.58	7.38	.12	1.22	7.02	3.74	6.58	− 4.04	− 6.77	−1.79	− 6.45
Spring wheat	6.72	6.81	2.86	7.02	.56	− .37	1.57	− .97	−2.70	− 3.35	− 5.09	−2.54	− 3.64

As an average for all the methods, winter wheat has proved more profitable at Huntley, Belle Fourche, Ardmore, Scottsbluff, North Platte, Akron, and Hays. Spring wheat has been slightly more profitable at Judith Basin and Archer. At the remaining stations an average of all the methods shows a loss for both crops. At Amarillo the average loss is less for winter wheat, while at Garden City, Dal-

hart, and Tucumcari it is greater. The greatest differences between the net returns from the two crops are $9.28 at Hays, $5.45 at North Platte, and $4.71 at Akron, all being in favor of winter wheat. At only 3 of the 13 stations (Garden City, Dalhart, and Tucumcari) are the returns from summer tillage greater for spring wheat than for winter wheat. At all the other stations winter wheat shows larger net returns after summer tillage than spring wheat.

These results indicate that winter wheat rather than spring wheat should be grown under conditions similar to those existing at Huntley, North Platte, Akron, and Hays, and probably at Scottsbluff, Belle Fourche, and Judith Basin. At Archer and Ardmore, where the results are available for only three years, the differences are so small that another year's work might alter the averages considerably. At Garden City, Dalhart, and Tucumcari neither of the crops has returned a profit by any method. At Amarillo, under the methods which have yielded profits, those from winter wheat have been greater than those from spring wheat.

CONCLUSIONS.

These conclusions apply only to the yields of winter wheat as affected by the cropping and cultivation of the one year immediately preceding growth.

(1) Some seasons are so unfavorable as to result in failure of the winter-wheat crop without regard to the cultural methods under investigation. Extremely unfavorable climatic conditions can not be overcome by cultural methods.

(2) It is only in those seasons when the rainfall deficit is so small that it can be overcome by moisture stored in the soil that the cultural methods under investigation have shown important effects upon yields.

(3) When the differences in the values of the yields are less than the differences in cost of production, then cost becomes the determining factor.

(4) Some soils, even in regions of profitable winter-wheat production, show little response to cultural methods.

(5) Reducing the cost of production has in most cases in these investigations proved a more important factor in determining profits than increasing the yields by cultural methods.

(6) The average difference in yields between early (deep) and late (shallow) fall plowing is 1 bushel per acre. At most stations the difference is small, while at others the advantage of one over the other depends on the season. At Scottsbluff, North Platte, Hays, and Amarillo the differences are rather consistently in favor of early plowing, and this method is more profitable at these stations. At the other stations late plowing has netted larger returns.

(7) Furrowing with a lister after harvest and leveling the ridges preparatory to seeding have resulted in an average increase of 0.9 bushel over early plowing and 2.2 bushels over late plowing. As it is a cheaper method of preparation than plowing, it has consequently been more profitable. At Hays and Amarillo it has been the most profitable method.

(8) Subsoiling has increased the yields over plowing without subsoiling at 5 of the 10 stations at which it has been studied. At these stations it has been more profitable than ordinary plowing. At the other stations it has been the least profitable of the continuous-cropping methods. It has not shown any value in overcoming drought.

(9) Disked corn ground has given consistently high yields. This, together with the low cost of preparation, has resulted in this method showing the highest average net returns of any of the methods at all of the 11 stations where it has been tried except at Huntley and Amarillo. These profits are based on the assumption that the corn crop was so utilized as to pay for the cost of producing it.

(10) Summer tillage has given the highest average yields of any method under trial at 11 of the 13 stations. However, on account of its high cost, due to extra labor and alternate-year cropping, it has not netted the largest returns except at Huntley.

(11) Green manuring is the most expensive method under investigation. It has given the smallest net returns of any of the methods at all of the stations except Huntley, where the profit from it is slightly greater than from either fall plowing or subsoiling.

(12) In comparison with spring wheat, winter wheat shows a greater response to summer tillage and is the more profitable crop to grow on land so prepared. This appears to be true at all stations studied except possibly Garden City, Dalhart, and Tucumcari, where large average losses attend the growth of either crop.

In the average of all methods by which the crops are grown winter wheat has a marked advantage over spring wheat, both in yields and profits per acre, at North Platte, Akron, and Hays in the central portion of the Great Plains and at Huntley, Mont. At the other stations, where either crop can be grown profitably, the average differences in favor of either are not great enough to be conclusive from the evidence at hand.

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